

## **2. HISTORICAL PERSPECTIVE**

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Since first formulated over a century ago, trichloroethylene (TCE) and tetrachloroethylene (PCE) have been used extensively for degreasing metal parts, dry cleaning, and many other industrial purposes. Over time, the use, storage, and disposal of these chemicals led to significant pollution of the nation's surface water and groundwater resources. This section summarizes the historical knowledge of the toxicology of TCE and PCE, drinking water regulations, and the drinking water industry's knowledge of the chemicals and their prevalence in groundwater during the 1980–1985 time frame—when Camp Lejeune first identified the contaminants in its drinking water.

### **2.1 Industrial Uses of TCE and PCE**

TCE and PCE are considered synthetic organic chemicals (SOCs). TCE was first synthesized in 1864 and its use continued to expand, particularly during and after World War II, reaching peak production in 1970 (Doherty, 2000a). PCE was first synthesized in 1821. Its use and production expanded in a pattern similar to TCE, and production of PCE also peaked in 1970 (Doherty, 2000b).

Use of TCE as a dry cleaning solvent expanded in the 1930s. In the 1940s, TCE as a drycleaning solvent was discontinued when it was found to attack certain cellulose acetate dyes. The primary use of TCE transitioned to vapor degreasing of metals parts. By the early 1950s, 92 percent of TCE was consumed in vapor degreasing (Doherty, 2000a). From the 1950s through the mid 1970s, TCE was also used as a general and obstetrical anesthetic; grain fumigant; skin, wound, and surgical disinfectant; pet food additive; extractant of spice oleoresins in food; and extractant of caffeine for production of decaffeinated coffee. The U.S. Food and Drug Administration banned these uses in 1977 (Doherty, 2000a). TCE was marketed to consumers as a cleaner for home septic systems, to be used on a regular, long-term basis to prevent blockages in waste pipes. This usage contributed to the contamination of major groundwater resources in the United States. During the 1980s, approximately 80 percent of TCE was used in cleaning and degreasing.

PCE was not used extensively until the 1940s, when it began to replace TCE in the dry cleaning industry. By 1967, 88 percent of PCE was used in the dry cleaning industry. Although dry cleaning

continued to be the primary use of PCE, the amount of PCE used in the dry cleaning process decreased substantially in the 1980s due to improvements in the dry cleaning equipment and vapor recovery systems. The growth in use of wash-and-wear fabrics and new environmental regulations also reduced its use (Doherty, 2000b).

## 2.2 Use of TCE and PCE at/near Camp Lejeune

TCE, the primary contaminant of concern in the Hadnot Point drinking water system at Camp Lejeune, was present due to past disposal practices in the area. These disposal practices were common in the United States prior to the late 1970s. In a September 15, 1985 *Raleigh News & Observer* article on Camp Lejeune, the following statement was reported:

*“Arthur E. Linton, federal facilities coordinator for the EPA’s southeast region in Atlanta, said Camp Lejeune and other military installations had disposed of waste in ways that were accepted practices in the past. ‘The military hasn’t done anything that wasn’t done in the private sector,’ he said.”* (Allegood, 1985)

PCE in the Tarawa Terrace drinking water system originated from ABC Drycleaners, which began operations in 1954. The two wells contaminated from these operations, TT-26 and TT-23, were located approximately 900 feet and 1,800 feet from the cleaners, respectively. Well TT-26 was drilled in 1952, and TT-23 in 1984. The base closed both wells in February 1985. It is not known how long the groundwater around those wells was contaminated before closure.

## 2.3 Regulatory Framework

The U.S. Environmental Protection Agency (EPA), the State of North Carolina, and other governmental agencies regulate public drinking water systems and the discharge of wastes into surface water bodies to ensure that our surface waters are fishable, swimmable, and protected, and drinking water is safe. In 1972, Congress passed the Federal Water Pollution Control Act (FWPCA), which mandated major changes in the way water quality would be controlled in the United States. This regulation provided the basis for the water quality programs used today. The objective of the act was to “...restore and maintain the chemical, physical and biological integrity of the Nation’s waters.” If met, the objective would ensure a safe drinking water supply and that all waters of the nations were fit for fishing and swimming. The Clean Water Act (CWA) amended the FWPCA in 1977. The CWA controls discharges of pollutants into waters of the United States through a system of ambient water quality standards and pollutant discharge permits issued to point sources.

In 1974, Congress passed the Safe Drinking Water Act (SDWA) to address the public's growing concern over contamination of domestic drinking water supplies with SOCs and other pollutants (P.L. 93-523, 1974). The SDWA was implemented in three steps:

Step 1. Develop National Interim Primary Drinking Water Regulations (NIPDWRs).

Step 2. Arrange for the National Academy of Sciences (NAS), a Congressionally chartered organization not a part of the federal government, to assess the health effects of contaminants in drinking water to provide proposed recommended maximum contaminant levels (RMCLs).

Step 3. Promulgate National Primary Drinking Water Regulations (NPDWRs) that would include RMCLs, MCLs, and monitoring and reporting requirements for those contaminants that may have an adverse effect on human health.

### **2.3.1 National Interim Primary Drinking Water Regulations (1975–1980)**

The purpose of the NIPDWRs was to protect human health based on either MCLs for specific pollutants or treatment technologies to remove the pollutants and “secondary standards” to protect the aesthetic quality of drinking water. The regulation was intended to protect public water systems and ensure that they supplied potable waters free of biological, chemical, or physical contaminants (Sullivan et al, 2001). A public water system is a system that has at least 15 service connections or serves 25 or more people for at least 60 days per year. A community water system is a public water system that serves a resident population. During the 1980–1985 timeframe, Camp Lejeune operated eight community water systems.

The NIPDWRs for numerous microbiological, inorganic, organic, and radionuclide contaminants were published on December 24, 1975, and became effective on June 24, 1977. Amendments were issued in 1976, 1979, and 1980. The MCLs and monitoring and reporting requirements for these NIPDWRs were based on the 1962 U.S. Public Health Service standards for drinking water, which in turn were derived from previous standards dating back to 1915 for microbiological standards and 1948 for inorganic chemicals (Sullivan et al, 2001). TCE and PCE were not among the contaminants included in these NIPDWRs.

The 1979 NIPDWR amendments provided the final regulations for the control of total trihalomethanes (TTHMs), which established an MCL of 0.10 parts per millions for TTHMs in drinking water and provided a schedule for compliance and monitoring. This regulation required

that any water treatment system serving between 10,000 and 75,000 people begin mandatory monitoring of TTHMs by November 1982, and compliance with the MCL was required by November 1983 (NIPDWR, 1979). In preparation for TTHM compliance, the Marine Corps began sampling its drinking water system in 1980, which led to the identification of volatile organic compounds (VOCs).

EPA requested that NAS conduct a study of the health effects of contaminants in drinking water, including TCE and PCE. NAS submitted its report in 1977 (NAS, 1977), followed by eight additional reports. The NAS reports provided EPA with toxicological assessments of contaminants in drinking water but did not provide RMCLs, which are non-enforceable health goals such that there are no adverse health effects if humans are exposed to this level of the contaminant for a lifetime. NAS did develop “suggested no adverse response levels” (SNARLs) for 1-day and 10-day exposure, which EPA used as a basis for its SNARLs. NAS elected not to establish a long-term SNARL due to lack of sufficient data and determined that development of RMCLs was EPA’s responsibility.

### **2.3.2 Suggested No Adverse Response Levels for TCE and PCE (1979–1980)**

During development of the NPDWRs for TCE and PCE, EPA issued an interim non-enforceable guidance for community water systems regarding acceptable limits of TCE and PCE in drinking water. In November 1979, EPA issued a SNARL for the non-carcinogenic risks associated with short- and long-term exposures to TCE. The 1-day SNARL for TCE was set at 2,000 µg/L and the 10-day SNARL was set at 200 µg/L. The long-term (based on a 70-year exposure) SNARL for TCE was set up 75 µg/L. EPA did not issue guidance on actions to be taken by the community water system if TCE concentrations in drinking water exceeded these values.

EPA issued a SNARL for PCE on February 6, 1980. The 1-day, 10-day, and long-term (70 years) SNARLS for PCE when the primary exposure route is drinking water were set at 2,300 µg/L, 175 µg/L, and 20 µg/L, respectively. EPA also issued Suggested Action Guidance for PCE in April 1980 related to contamination from coated asbestos-cement pipe. This pipe, used for water distribution lines, was coated with vinyl toluene to prevent pipe degradation from erosion. Water utilities in New England had documented leaching of PCE from this pipe, with the highest values found in “dead ends” of the system with low flow (Larson et al, 1983). The PCE concentration in

the pipes decreased over time and was usually not detectable after approximately five years. The EPA guidance recommended that the community water system take remedial action within 24 hours if the PCE concentration exceeded the 1-day SNARL and take remedial action within 10 days if the PCE concentration exceeded the 10-day SNARL. The guidance also recommended that PCE concentration should not exceed 40 µg/L for any extended period.

### **2.3.3 National Primary Drinking Water Regulations for TCE and PCE (SDWA, 1982–1992)**

The third step in the SDWA process required EPA to propose and promulgate NPDWRs, including RMCLs, MCLs, and monitoring and reporting requirements, for 83 contaminants that may have an adverse effect on human health. Promulgation of the 83 contaminants was planned in four phases:

Phase I. Volatile synthetic organic chemicals (VOCs, including TCE and PCE)

Phase II. Synthetic organic chemicals, inorganic chemicals, and microbiological contaminants

Phase III. Radionuclides

Phase IV. Disinfection by-products, including trihalomethanes

EPA published an Advanced Notice of Proposed Rule Making (ANPRM) for Phase I VOCs in March 1982 and held several public workshops to discuss the proposed rule (EPA, 47 FR 24330, 1982). EPA used “negotiated rulemaking” to develop the MCLs, which allows the regulated community and other individuals with an interest or expertise to participate in the rulemaking.

The proposed rule for Phase I VOCs, published in the *Federal Register* on June 12, 1984 (EPA, 49 FR 24330, 1984), set the RMCL for TCE and PCE at zero, based on each chemicals’ potential as a carcinogen. EPA published a proposed NPDWR for TCE in November 1985 (EPA, 50 FR 1774, 1985). The final NPDWR for TCE, which prescribed an MCL of 5 µg/L and monitoring, reporting, and public notification requirements, was published on July 8, 1987 (EPA, 52 FR 25690, 1987). The NPDWR for TCE took effect on January 9, 1989. The NPDWR for PCE was published on July 8, 1987, which included an MCL of 5 µg/L and monitoring, reporting, and public notification requirements (EPA, 52 FR 25690, 1987). The NPDWR for PCE took effect in 1992. North Carolina obtained primacy in 1982 and enforces drinking water regulations.

## **2.4 Development of Toxicity Data for TCE and PCE**

The administrative record shows that several chlorinated VOCs were identified in the groundwater and tap water at Camp Lejeune during the early 1980s. Because the closure of drinking water supply wells at the base resulted from detections of TCE and PCE, the Panel addresses only these two VOCs in this report.

Although information about the toxic properties of TCE and PCE had been developed and was widely disseminated during the 1980–1985 period, our knowledge of their toxic properties has expanded considerably since that time. For the purposes of this investigation, the Panel reports only those medical consequences of TCE or PCE that were reported in authoritative sources and represented a broad consensus in the scientific community, not only in the United States but also among developed countries worldwide. Two organizations cited in this discussion are the World Health Organization (WHO) and NAS. Over the years, both of these organizations have evaluated the effects of human exposure to TCE and PCE, including exposure from drinking water.

The historical development of toxicity information for TCE and PCE is summarized from Sullivan et al, 2001, unless otherwise noted. The primary human health effects of high (non-environmental) TCE and PCE exposure are non-carcinogenic, involving central nervous system (CNS) dysfunction and liver and kidney damage. CNS effects include depression, dizziness, headache, vertigo, and behavioral effects. Other adverse effects on mucous membranes, eyes, skin, kidneys and lungs have also been noted. TCE and PCE have been found to cause cancer in laboratory animals under certain conditions. EPA has identified both agents as potential carcinogens.

### **2.4.1 Trichloroethylene**

The first industrial reports of TCE toxicity were reported in 1915 when an acute toxic syndrome was noted. Most information regarding the toxicology of TCE was established during the 1930s. The first extensive medical study of industrial health effects from TCE was published in 1932. A 1937 study identified adverse effects to the CNS, gastrointestinal system, and circulatory system as a result of TCE and PCE exposure.

Prior to 1980, NAS documented the effects of TCE inhalation as having the ability to depress the CNS in humans causing loss of coordination and unconsciousness and cause kidney and liver

damage in laboratory animals (NAS, 1977). The kidney and liver damage in laboratory animals was believed to be predictive of human responses. TCE, when ingested for a lifetime, was also considered a liver carcinogen in mice. The cancer risk to humans from consuming 1 µg/L of TCE in water was estimated to be approximately one in ten million over a 70-year lifespan (NAS, 1977). NAS also reported that TCE was found to cause no birth defects in highly exposed laboratory animals.

In 1980, NAS expanded its earlier assessment and stated that TCE is not only a carcinogen but also is capable of causing mutations of genetic material, which may be the mechanism by which it causes cancer. NAS pointed out that the cancer-causing effect increased with increasing dose—an observation that provided greater scientific weight to TCE's cancer potential (NAS, 1980). This volume first reported a SNARL for TCE of 15,000 µg/L in tap water for an exposure of no more than seven days. NAS went on to state that because it is “not possible to establish a ‘no effect level’ for chronic, non-carcinogenic toxicity,” no safe level of chronic exposure could be estimated. This report was used in development of EPA's SNARL for TCE, which was issued later that year. In 1981, the WHO recommended a tentative guideline of 30 µg/L TCE in drinking water for a lifetime exposure (WHO, 1984).

By 1983, NAS pointed out that progress had been made in understanding how TCE causes cancer and liver toxicity. The 1983 report went on to estimate the cancer risk for humans, by gender, ingesting 1µg/L TCE via drinking water. The cancer risk for males was estimated at four in ten million for a lifetime of exposure and 0.7 in ten million for females—indicating that males are more susceptible to carcinogenic properties of TCE than females. Again, NAS was unable to estimate a non-cancer SNARL for chronic exposure (NAS, 1983).

WHO issued its first report on TCE in 1985. This report closely paralleled the NAS findings in many respects. WHO reported on the depression of the central nervous system, liver toxicity, carcinogenicity, and mutagenicity of TCE. WHO found “clear evidence” for the carcinogenicity of TCE and noted the production of not only liver tumors but also tumors of the lung and testes (WHO, 1985).

Another reference available in workplaces across the U.S. was Patty's Industrial Hygiene and Toxicology. The 1981 edition noted the toxicity of TCE to the nervous system, liver, and kidneys, similar to the NAS's descriptions in 1977 and 1980; however, the Patty's authors did not find the evidence for genetic damage or cancer to be sufficiently compelling to be considered a problem in the workplace (Patty's, 1981).

#### **2.4.2 Tetrachloroethylene**

The chronic toxicity of PCE to laboratory animals was reported in 1937; the most sensitive target organ was the kidney. Although there was some controversy regarding the toxicity of PCE in the 1940s, the maximum allowable air concentration in the workplace was reduced from 200 ppm to 100 ppm (200,000 µg/L to 100,000 µg/L) in 1947.

Prior to 1980, NAS documented the effects of PCE inhalation as having the ability to depress the central nervous system in humans causing loss of coordination and unconsciousness. NAS found that PCE when inhaled at high concentrations for long periods of time did not produce toxicity in species believed to be predictive of human responses, such as rats, rabbits, guinea pigs, and monkeys. NAS also reported that PCE caused no birth defects in highly exposed laboratory animals. PCE had not yet been tested for carcinogenicity (NAS, 1977).

In 1980, NAS expanded its earlier assessment of PCE and noted that in sufficiently high doses, PCE is a "*portent depressant of the central nervous system.*" PCE also was reported to cause liver injury several days after exposure, as well as kidney damage. With increasing duration of exposure, kidney damage became increasingly severe. The NAS report also found that PCE did not produce genetic damage and that, despite PCE being toxic to developing embryos whose mothers had been exposed, it did not produce skeletal malformations. PCE's potential carcinogenicity was drawn from a study performed by the National Cancer Institute that found that PCE produced liver cancer in both laboratory rats and mice. Using this data, NAS calculated an estimated cancer risk for humans of 0.6 per ten million individuals when exposed to 1 µg/L of PCE in drinking water over a lifetime (NAS, 1980).

The NAS 1980 report also suggested a SNARL of 25,000 µg/L in drinking water for an exposure of no more than seven days. Further, NAS stated that because it is "*not possible to establish a 'no effect level'*"

*for chronic, non-carcinogenic toxicity,”* no safe level of chronic exposure can be estimated. EPA used this report when developing its SNARL for PCE, which was issued later that year. In 1981, the WHO recommended tentative guidelines of 10 µg/L PCE in drinking water for a lifetime exposure (49 FR 24341, 1984).

By 1983, NAS pointed out that progress had been made in understanding the metabolism of PCE in the body and its role in producing liver toxicity. The 1983 NAS report declined to estimate the cancer risk for humans ingesting PCE via drinking water. NAS recommended a non-cancer SNARL for chronic exposure to PCE through drinking water of 14 µg/L (NAS, 1983).

WHO issued its first report on PCE in 1984. WHO's report closely paralleled the findings of the NAS reports in many respects. WHO reported that PCE caused depression of the central nervous system, liver toxicity, and mutagenicity in humans. WHO found limited evidence of the carcinogenicity of PCE in mice and noted that epidemiologic evidence was insufficient to conclude that PCE causes cancer in humans (WHO, 1984).

The 1981 edition of Patty's noted the toxicity of PCE to the nervous system, liver, and kidneys, similar to the NAS's descriptions in 1977 and 1980. Patty's also noted that there was evidence that PCE exposure caused birth defects, but did not cause genetic mutations. PCE's carcinogenicity in animals was acknowledged without comment on the relevance to humans (Patty's, 1981).

### **2.4.3 Development of RMCLs for TCE and PCE**

When developing the proposed NPDWR for TCE and PCE (EPA, 49 FR 24330, 1984), EPA's Carcinogen Assessment Group (CAG) reviewed the available toxicological studies performed on humans and animals, including the conclusions of the International Agency for Research on Cancer (IARC), which stated there was limited evidence of TCE's or PCE's carcinogenicity based on experimental animal studies and inadequate evidence of carcinogenicity from available human data (49 FR 24341, 1984). In the end, CAG used data from high-dose animal studies to calculate projected excess cancer risk estimates when developing the RMCLs for TCE and PCE published in the proposed NPDWR.

## 2.5 Water Supply Industry Practice: 1980–1985

Groundwater contamination by TCE and PCE was documented in the 1960s and 1970s, and the water supply industry was aware that these contaminants could be present in source waters. Much of what was known about water quality, management, and pollution control prior to EPA's inception was shared through professional organizations such as the American Water Works Association (AWWA). AWWA, established in 1881, is one of the most respected professional organizations in the water supply industry. AWWA began transmitting information to its members through publications and meetings in the 1920s (Sullivan et al, 2001). AWWA's local section in North Carolina in the early 1980s had approximately 600 of the 32,000 nationwide members.

### 2.5.1 EPA and the Water Supply Industry

By 1980, EPA had been operational for a decade. The Agency expended considerable effort informing the water supply industry of new and proposed regulations, as well as the Agency's priorities and approaches. EPA distributed information documenting the activities of NAS in the *Drinking Water and Health* series, whose first volume was issued in 1977. It is unclear whether water works operators of military installations were recipients of this information; however, one would have expected them to be at least generally aware of EPA's activities.

In the early 1980s EPA also developed a non-regulatory program to provide water utilities and state and local health agencies with information regarding the toxic properties of chemicals commonly found in drinking water and the safe levels of human exposure to these substances. This program produced "Health Advisories" on specific substances. The Health Advisories were widely sought by state and local agencies and were known to at least some parts of the military, including Camp Lejeune. It is unclear how the informal guidance in EPA's Health Advisories was received by Camp Lejeune water works professionals in this context. These documents were perceived as reliable evaluations of health (i.e., toxicological and epidemiological) data and useful for determining safe/unsafe levels of chemicals in drinking water. Indeed, some states and water utilities often treated these levels as *de facto* standards to guide water treatment practices and to decide on whether to alert consumers about possible health threats.

Most water utilities disinfected their drinking water sources prior to delivery to customers. During the late 1970s, EPA discovered that disinfection of drinking water could form chlorination

byproducts (generally now referred to as disinfection by-products or DBP), some of which were considered carcinogens. Water supply industry professionals were skeptical of this new “risk.”

In the early 1980s, the water supply industry, by and large, used conventional water treatment techniques to comply with enforceable regulations, but did not monitor or treat for unregulated compounds. Typically, the water supply industry waited until regulations were finalized before changing their practices, since the cost of compliance with regulations was unavoidable. While no documentation exists to indicate how the Marines at Camp Lejeune sought to address unregulated substances such as TCE and PCE, it is reasonable to conclude that Camp Lejeune water works professionals were in step with the rest of the industry—waiting until legal standards were issued before altering water treatment and monitoring practices. The administrative record at Camp Lejeune clearly demonstrates a willingness to comply with the new THM standards being promulgated by EPA.

The Journal of AWWA (JAWWA), published monthly, is a forum for members to publish papers that address the primary issues concerning public water systems, such as water treatment technologies, distribution systems, water quality monitoring, and upcoming or recently promulgated regulations. The Panel reviewed abstracts for all articles published in JAWWA between January 1980 and December 1985 to ascertain the state of the industry’s knowledge regarding the potential for TCE and PCE contamination of groundwater, status of monitoring and analysis techniques for TCE and PCE, and recently enacted and upcoming drinking water regulations (particularly those related to TCE and PCE). Pertinent articles are discussed in the text below.

#### ***2.5.1.1. The Water Supply Industry and SOCs***

Review of the 1980 JAWWA abstracts provided four articles that discussed synthetic organic chemicals, including TCE and PCE. One article in particular highlighted the industry’s emerging realization that groundwater contamination by TCE and PCE was becoming more widespread (Trussell and Trussell, 1980). This article discussed approaches a system might use to evaluate the purity of its water source, review the effectiveness of its current treatment, assess the risk of exposure to consumers, study the feasibility of various courses of action if contamination is identified, and implement a final plan. Six steps were identified in the process: source

evaluation, risk assessment, feasibility analysis, scheduled periodic surveillance, cost-benefit analysis, and implementation.

In November 1979, EPA had amended the NIPDWRs to include a final regulation setting an MCL of 100 µg/L for TTHMs in drinking water (Singer et al, 1981). This regulation required that water systems begin monitoring for TTHMs; the monitoring requirements were phased in depending upon system size. For systems serving 10,000–75,000 people, such as Hadnot Point, regulation mandated monitoring by November 29, 1982 and compliance by November 29, 1983. These federal regulations did not apply to community water systems serving less than 10,000 people (e.g., Tarawa Terrace) and left primacy over these small systems to individual states. The analytical method used to determine TTHM also showed peaks that represented other SOC's present in the water. These peaks could alert the community water system to the potential that there were industrial sources contaminating the groundwater.

Although there were no enforceable MCLs for the SOC's identified in these groundwater supplies, some articles published in JAWWA took the position that the public should not be provided drinking water containing SOC's. This statement from Petura, 1981, is similar to others in these articles:

*"The contamination of groundwater resources by substances such as TCE and methylene chloride has created a dilemma that requires the attention of public health officials and professional specialists in chemistry, hydrogeology, and environmental engineering. Each situation is unique and should be studied carefully before any conclusions are reached and action is taken. However, because these materials cannot be detected via the senses until the concentrations reach toxic levels, expeditious action must be taken to protect public health."*

By 1982, groundwater contamination was receiving much attention in the water supply industry. The theme of the August 1982 issue of JAWWA was organic contamination in groundwater. In the JAWWA editor's summary of the theme, he stated, "...water utilities that rely heavily on groundwater, particularly the thousands of small systems, should guard against sources of pollution and should take immediate steps to monitor and treat supplies that have already been tinged with organic and other contaminants." The issue included reports on research in progress to manage groundwater quality, presented methods of treating already polluted sources most economically, and cited a case history of how one community groundwater supply was being managed to further prevent intrusion of contamination (Dyksen and Hess, 1982).

No JAWWA articles or reports were found in the Camp Lejeune administrative record.

#### **2.5.1.2. Leaching of PCE from Asbestos-Cement Pipe**

During late 1979 and early 1980, there was interest on the part of many states, water utilities, individuals, and the EPA in the leaching of PCE from vinyl toluene-lined asbestos-cement (A-C) pipe. The issue was a concern to EPA and prompted the Suggested Action Guidance for PCE (USEPA, 1980b).

The April 1983 issue of JAWWA contained an article by Larson *et al* that discussed the options that the homeowner, community water system, state, and EPA could take to reduce the public's exposure to PCE in drinking water from this source. This article was followed by a discussion of the issue from the perspective of the pipe manufacturer, a water utility operator, and a toxicologist. The article suggested that the CWS install blowoffs and flush lines near the dead ends of the system, where the highest concentrations were usually observed, and notify effected homeowners and identify actions the homeowners could take to reduce their exposure. The article states that the current activities consist primarily of flushing and bleeding lines (due to the highest concentrations being in dead ends) (Larson *et al*, 1983).

When the American Water Works Service Co. (AWWSC) was alerted to the potential PCE problem in 1980, it began an extensive sampling program to determine if leaching was a problem in its pipe. The company identified two areas with high PCE and then continued testing in these two areas. AWWSC installed a blowoff to increase water flow in the areas and keep PCE levels below EPA's recommendations (Moser, 1980).

#### **2.5.2 Small Community Water Systems and NIPDWRs**

The National Interim Primary Drinking Water Regulations applied to 60,000 community water systems and 160,000 non-community water systems. Implementation of the NIPDWRs pointed out a number of water quality and management problems. For instance, in fiscal year 1982, more than 70,000 violations of the interim regulations were recorded by 20,000 community water systems. Eighty-four percent of these violations were for monitoring and reporting; however, more than 9,000 community water systems required improved facilities to meet drinking water standards.

In 1982, the microbiological requirements were not continuously met by many of the smaller systems that served fewer than 3,300 persons; 10 percent of the systems violated the MCL requirements and more than 25 percent violated the monitoring requirements. Small community water systems tended to also have problems meeting the MCLs for certain inorganic chemicals. This problem was found primarily with small systems using groundwater, since removal of inorganic chemicals can be difficult and relatively expensive on a per capita basis.

Compliance problems related to MCLs and monitoring and reporting were often associated with small systems because they frequently have limited financial and human resources available. According to Cortuvo and Vogt (1984), EPA was considering revising the regulations to identify technologies that were economically achievable for small systems. These technologies would assist the states in issuing variances when a small community water system could not meet the requirements because of the characteristics of its raw water sources.

## **2.6 AWWA's Response to the ANPRM for Phase I VOCs**

The AWWA provided comments to EPA on the Advanced Notice of Proposed Rulemaking for Phase I VOCs, which included TCE and PCE. These comments were summarized in the "Summary of Public Comments" section of the proposed rule for Phase I VOCs (49 FR 24332, 1984) published in June 1984. AWWA recommended that contaminants be controlled at their source through EPA's existing statutory authorities but did not think MCLs were appropriate at that time because "safe" levels of VOCs could not be determined using existing health-effects data. The AWWA suggested that an MCL be established if a significant health risk exists after data have been evaluated by a recognized scientific organization such as the NAS.

In the interim, AWWA recommended that national monitoring for specific compound identification should be implemented for all water supplies, but requirements for community water systems serving less than 10,000 people, such as Camp Lejeune, would be at the discretion of the state. It is unclear if AWWA felt that community water systems serving less than 10,000 people should conduct limited monitoring or no monitoring at all. The AWWA comments concluded by requesting guidance in the form of contamination levels and action categories for five of the VOCs (including TCE and PCE) for all water supplies.

## **2.7 Drinking Water Regulation in California: 1980–1985**

Research on the activities and regulatory approaches in the State of California during the 1980–1985 period can provide insight on water utility practices and provide a yardstick for assessing Camp Lejeune's performance. California advocated that EPA adopt SNARLS. In 1985, the State Legislature adopted comprehensive drinking water monitoring requirements after TCE and PCE were discovered in the groundwater in the late 1970s and early 1980s.

Military bases generally are recognized to be responsive to MCLs, but do not give budget priority to complying with advisories; and military bases have been firm in dealing with microbial contaminants and TTHM requirements. Prior to the adoption of MCLs for TCE and PCE, California Department of Health Services recommended that customers be notified, provided action level (5 µg/L) guidance, and suggested that supplies be removed from service when concentrations exceeded 100 times the action level.

The early cases of TCE contamination in California, including Rancho Cordova and the Santa Clara Valley, came about by monitoring of underground injection of wastes from nearby industries. Contaminants were detected when new analytical techniques were developed; however, measurements were not always accurate. In some instances, detection occurred as a result of employees smelling the contaminants in the water. Use of wellhead treatment was pioneered during the early 1980s, but not reliably perfected until 1984 or 1985. Military bases in California, such as Camp Pendleton, that had significant groundwater contamination problems felt it was their responsibility to comply with MCLs, but not SNARLS.

## **2.8 VOCs at Camp Pendleton: 1980–1985**

The events at Camp Pendleton, California, could illustrate the Marine Corps practices with regard to VOCs in the early 1980s. Discussions with Pendleton staff (Kalique Kahn, Water Quality and Tracy Sahagun, Waste Management) have indicated that while VOCs and particularly TCE were used and disposed of at Camp Pendleton, water sampling has not detected VOCs in any of the base's water supply wells. These wells were and remain the source of water supply for the base. The base complied with the SDWA requirements, including MCLs as they were established. Even though VOCs were used and disposed of on the base in the same watershed as the drinking water wells, Pendleton did not test for VOCs until MCLs and their associated testing protocols were established

in 1989. The base considered TCE and PCE to be hazardous materials and disposed of them in accordance with existing requirements.

## 2.9 Summary

In the early 1980s, evidence continued to accumulate within the scientific community that synthetic chemicals, such as VOCs, created significant health risks as a result of long-term exposure. EPA adopted SNARL guidelines that influenced certain utilities to do further monitoring and undertake control measures. Articles in JAWWA in 1980 and 1982 indicate regulation of VOCs was being considered and describe both monitoring and treatment techniques that utilities could use to control them. Despite increasing discussion of these issues within the water supply industry, few utilities invested in control systems prior to the proposal or adoption of an MCL for a given chemical. Recent experience with arsenic control is an example. Further, professional journals are not often read by or disseminated to the people in the field who are struggling to comply with new requirements, particularly during the time period on which the Panel is focusing.

There is nothing in the administrative record to indicate that personnel at Camp Lejeune were aware of either NAS or WHO reports on the toxicity of TCE and PCE, although at least the NAS reports were widely read by the U.S. water supply industry and used as reference materials by some water utilities in the early 1980s and later.

A 1982 memorandum shows that in 1982 base personnel had a copy of EPA's SNARL for TCE, SNARL for PCE, and Suggested Action Guidance for PCE. These documents summarized the toxic properties, including cancer causing potential for humans, of each compound and provided safe, non-cancer levels for durations of exposure for as much as lifetime. While the SNARLS were not enforceable regulatory values, they informed the water supply industry, as well as State and local health authorities, of the potential dangers from drinking water containing TCE and/or PCE.

At Camp Lejeune, it is unclear who might have been aware of this toxicity information due, in part, to administrative arrangements. Specifically, the Water Treatment Division was responsible for monitoring water quality, particularly for regulated substances such as TTHMs. A group called Preventive Medicine would usually be expected to provide information such as SNARLS to the Environmental Division to help understand the significance of chemical measurements.

Furthermore, LANTDIV would have been expected to provide guidance as to the nature and severity of any observed contamination. Finally, the USMC's parent organization, the Navy, provided toxicological guidance through its Bureau of Medicine. Nowhere in the administrative record or in the interviews was there any indication of contributions from these organizations supporting the base's water supply program or its chain of command on this matter. By contrast, considerable documentation indicates that Camp Lejeune was given support from inside and outside the military on dealing with the then newly regulated TTHMs.

The records available to the Panel show that the base made every effort to comply with MCLs and related schedules, but not to anticipate or independently evaluate health risks associated with compounds that might be subject to future regulation (even though SNARLs existed for TCE and PCE). This appears to have been a fundamental policy, which would have overridden any possible issues of divided organizational responsibility between Camp Lejeune and LANTDIV personnel. The Panel's review indicated that Camp Lejeune provided water that had a quality consistent with average civilian utilities in the United States and was also consistent with military practice. It is true that some utilities, while there were changing water regulatory requirements in the early 1980s, took early action to eliminate or treat VOC-contaminated sources before being required to do so. Nevertheless, it appears to the Panel that Camp Lejeune exercised a reasonable standard of care considering general utility practices at the time.